MEMBRANE PLANTS IN SOUTH FLORIDA

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Resource Planning Department

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Desalination - A Viable Alternative in South Florida's Water Resources Planning

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ABSTRACT

There is a vast amount of brackish water in the Floridan formation of South Florida which is not used presently. This water can be treated by advanced techniques to bring it within "Safe Water Drinking Act" standards.

In water use planning for South Florida, one of the alternatives being investigated is the treatment of the aforementioned brackish water (TDS > 1,500 mg/l) by desalination techniques since this method has already reached commercial acceptance.

This paper will discuss the various techniques of desalination being presently used, compare the cost of different techniques to produce 1,000 gallons of potable product water, and compare the cost with the present water cost the consumers pay in South Florida.

The existing status of desalination plants in Florida will also be reviewed, and its potential future uses as a water management alternative will be discussed.

INTRODUCTION

"Water seems to be available in the wrong place, at the wrong time, and in the wrong quality."

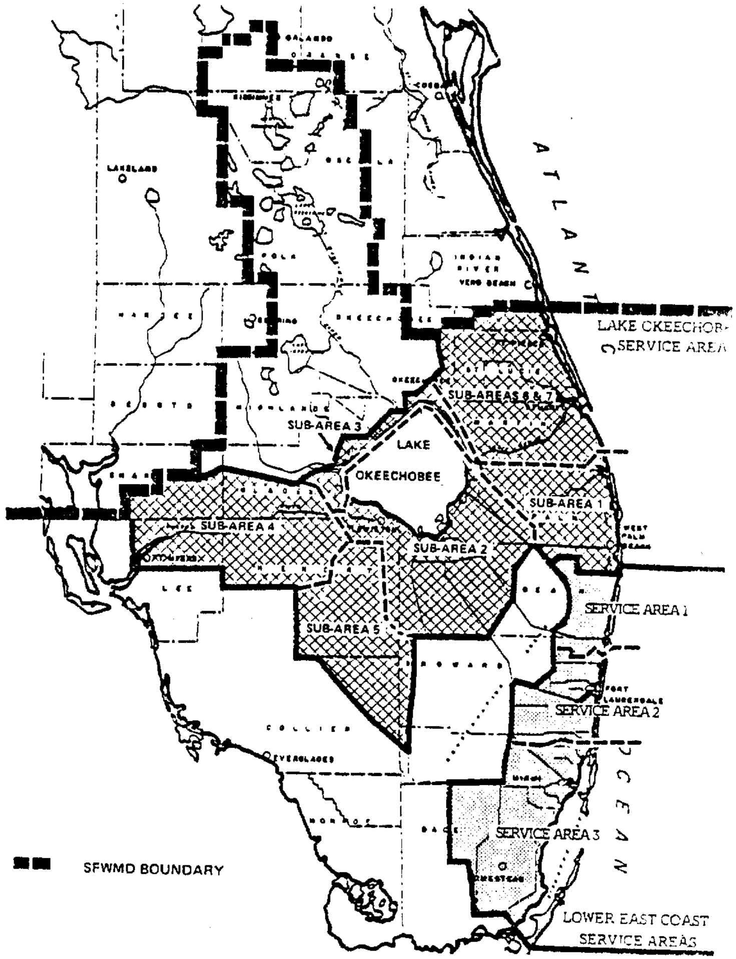
United Nation's Report

South Florida in a sense, is a water rich area receiving almost 60 inches of rain on a yearly average, with only a small percentage of this water consumed by man's activities.

When the region receives the average rainfall every year, no water problem occurs. Lake Okeechobee and the conservation areas have the capability of supplying water to the present population of the most heavily populated areas for some time into the future(see Map 1). However, with the ever increasing population and the vagaries of nature in terms of below average rainfall, (as it occurred during the 1970-71 drought - 38 inches), the South Florida Water Management District is undertaking the development of a water use and supply development plan for the region to meet future water requirements under a wide variety of growth conditions.

The water use plan in draft form is completed. The plan addressed 14 alternatives to meet the future water requirements of the region. The alternatives that were studied are:

1) Conservation
2) Regulation
3) Wellfield Development
4) Backpumping of Storm Water
5) Forward pumping
6) Additional Water Storage in Lake Okeechobee



MAP 1 - SERVICE AREAS WITHIN THE LOWER EAST COAST AND LAKE OKEECHOBEE AREAS
(CONSIDERED IN THE CURRENT DRAFT PLANS)

7) Desalination of Brackish Water

8) Deep Aquifer Storage

9) Reuse of Wastewater for Non-Potable Uses

10) Weather Modification

11) Desalination of Sea Water

12) Additional Surface Water Storage Areas

13) Evaporation Supression

14) Water Importation

Ten public workshops were held by the District in order to obtain feedback from the public. Public inputs were analyzed and the following alternatives received considerable positive public support:

1) Water Conservation

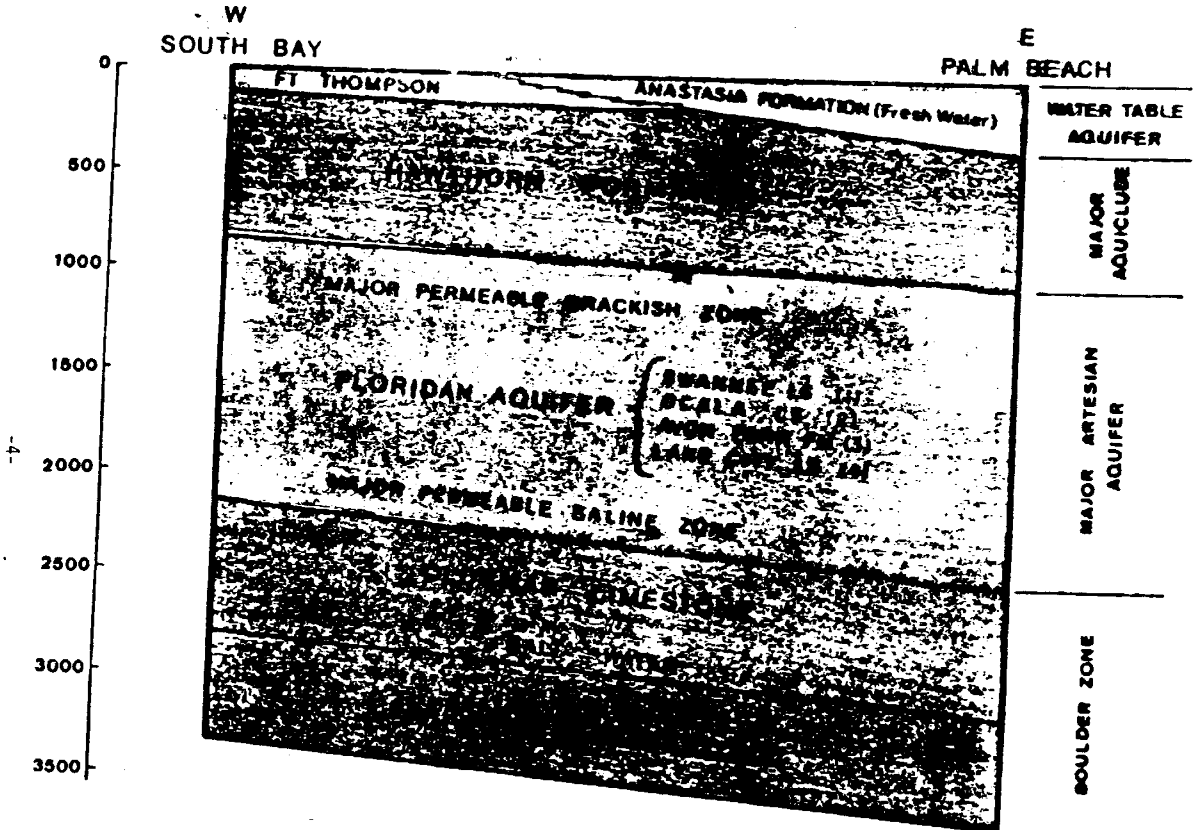
2) Desalination of Brackish Water

3) Reuse of Renovated Wastewater for Non-Potable Uses

This paper deals with the desalination of brackish water as one of the alternatives in south Florida's future water resource planning.

<u>Raw Water Source</u>

The potential source of raw water for the desalination alternative is the Floridan aquifer. This aquifer consists of a thin section of carbonate and evaporate rocks underlying all of Florida. The principle artesian zone of the aquifer ranges from 800 to 2100 ft. in south Florida (8) (see map 2). In south Florida water contained in this artesian formation is practically untapped at present, due to the saline nature of the water. Based on pump tests, if a 12 inch well is drilled to a depth in between 1100 to 1300 ft. MSL, the yield from this well is expected to be about 1600 GPM and the salinity



MAP 2

SCHEMATIC GEOLOGIC CROSS-SECTION FROM SOUTH BAY TO PALM BEACH about 2700 mg/l (8). The maximum recommended TDS level as per U. S. Public Health standards is 500 TDS. Therefore, in order for the water to be used for potable uses (500 mg/l TDS; 250 chlorides), desalting techniques would have to be used.

Presently 16 million gallons of water per day is pumped from this aquifer and desalted for potable and other uses on the coastal areas of south Florida.

Desalting Techniques

The basic fundamental process of any desalting technique is a separation process. Three main types of desalt techniques are used presently. They are: 1) distillation, 2) freezing, and 3) membranes. The Office of Saline Water Research (now OWRT) classifies water based on the TDS content as follows:

1) Brackish water $\leq$ 5000 TDS.
2) High saline water 5000 to 35,000 TDS.
3) Sea water $\geq$ 35,000 TDS.

Classically the distillation process of desalination has been used to produce pure water from high saline water and sea water. Even though the freezing process has not reached commercial scale so far, the process is also used with the same type of high saline water to produce fresh water.

The membrane and ion exchange process has been used to desalt brackish water and has reached commercial acceptance. Membrane desalting can be electrical (such as electrodialysis), and mechanical (as reverse osmosis). Ion exchange is a chemical process.

Ion Exchange is commercially used to purify low TDS $\leq$ 1500 mg/l water. The basic idea behind the process is exchanging calcium and magnesium with sodium ions (cation exchange).

Electrodialysis has been used to desalt brackish water in the range of 1500 to 5000 TDS. Electrodialysis is very sensitive to salt concentration. Electrical energy required is a function of salt concentration. If the TDS of the feed water goes up or if fresh water recovery is increased electrical consumption increases.

The alternative the District is researching involves the least cost power requirement process (see Figure 1). As stated earlier, reverse osmosis (hereafter referred to as RO) is a mechanical process. Pressure 5 to 50 times the osmostic pressure is applied to produce pure water. If the salinity of the feed water increases, the same pressure as applied previously will produce water of the same TDS content as before; however, there will be a slight drop in the quantity of water produced. However, reverse osmosis can also be used as a competitive water treatment technique by itself (see Table 1).

Reverse Osmosis

Osmosis is a natural phenomenon in which plants draw water out of the ground and up into their leaves. Moisture passes through the cell wall (which is a semi-permeable membrane) into areas of higher solute concentration.

From another perspective, osmosis may be viewed as a natural equilizing process when pure water, for instance, is separated from a salt solution by a semi-permeable membrane (a membrane which readily passes water, but not dissolved salts), the pure water will flow through the membrane and dilute the more concentrated salt solution to the other side.

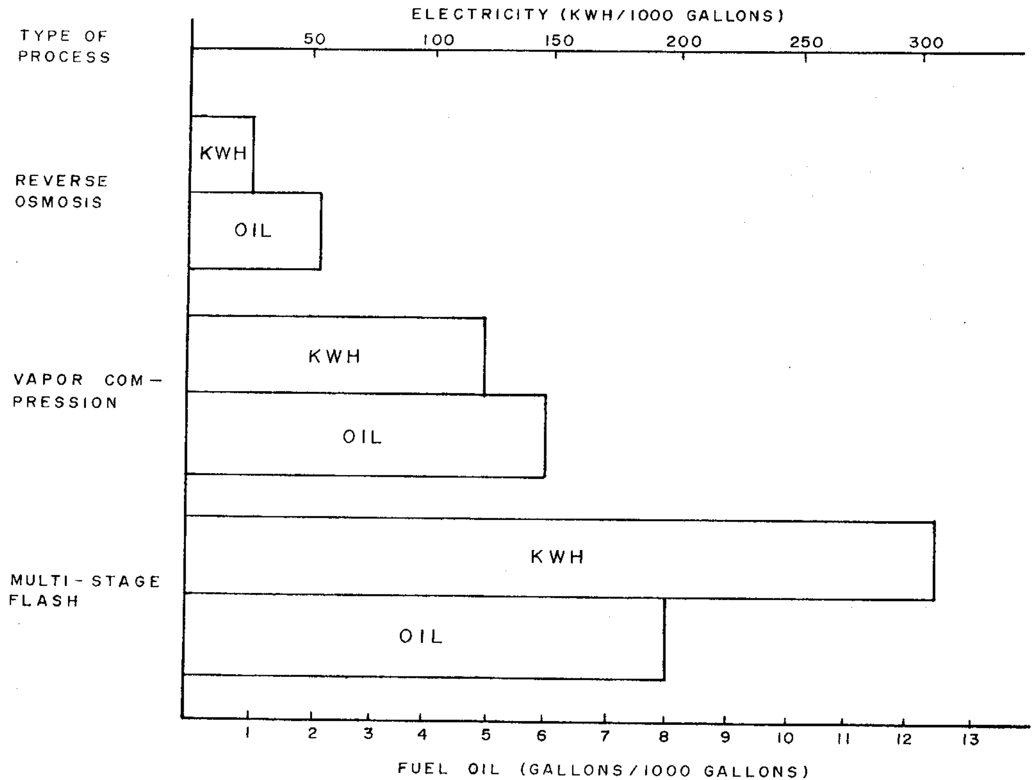


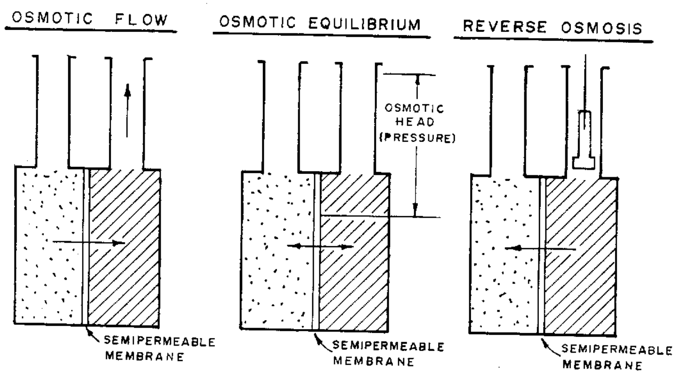
Figure 1 COMPARATIVE ENERGY REQUIREMENTS FOR SEAWATER DESALINATION

TABLE 1 THE REMOVAL OF POLLUTANTS FROM SURFACE WATER BY MEANS OF DIFFERENT TREATMENTS

	Chlorination	Coagulation	Reverse Osmosis	Active Carbon
Bacteria and viruses	XXX	XXX	XXX	-
Suspended matter	-	XXX	XXX	XX
Total organic carbon	-	XX	XXX	XXX
Pesticides	-	XX	XXX	XX
Inorganic salts	-	-	XXX	-
Inorganic toxic compounds	-	XX-XXX	XXX	-
Ammonia	(XXX)	-	X	-
Phenols	-	-	X	XXX
Taste and odor	-	X	XX-XXX	XXX
Oil	-	X	XXX	XX
Detergents	-	X	XXX	XXX
Hydrocarbons	-	-	X-XX	XXX
Chlorinated hydrocarbons	-	-	X-XX	XXX
Volatile organic acids	-	-	X	XX
Carbohydrates, Amino acids, Fatty acids, Proteins	-	X	XXX	XX

XXX 90-100% removal
XX 50-90% removal
X 10-50% removal
\- < 10% removal

In the process of reverse osmosis (RO), pressure is applied to the concentrated salt solution and the "flow" is reversed. Pure water is forced through the membrane in the opposite direction, leaving behind it all at the dissolved impurities (Figure 2).



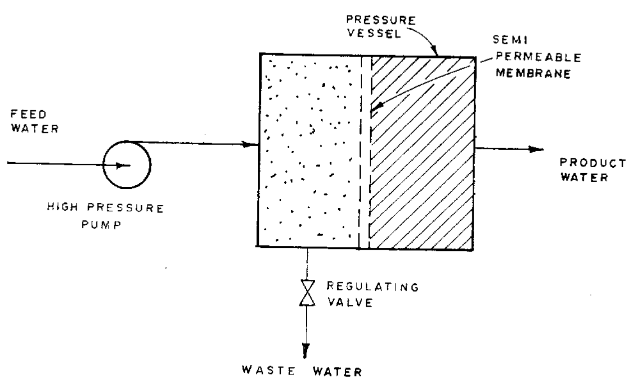


Figure 2 SCHEMATICS OF RO PROCESS

The feasibility of reverse osmosis as a desalting technique on a commercial basis started in 1960 when Dr. Loeb and Dr. Sourirajan developed the cellulose diacetate RO membrane capable of producing water fluxes of 5 to 8 gallons per square foot per day and up to 90 percent salt rejection.

Since 1960, significant advances have been made in brackish water membrane technology (6). Fluxes have been improved two to three times, and a new family of membranes designated as "ultra-thin composites" have been developed.

In its simplest form, a RO system unit consists of a membrane, a structure to support the membrane, a vessel to contain the pressure, and a pump to pressurize the brackish water. Pump pressure is the exclusive driving force for RO.

Pre-treatment

An inherent disadvantage of any membrane process in solute-solvent separation is the tendency of the membrane to become fouled with any particulate or collidal matter present in the feed solution. In RO processes, the particulates form a very thin layer on the membrane surface, thereby preventing direct contact of the saline solution with the desalination barrier. This reduces the rates of fresh water. In addition to particulate matter a number of salts ($CaSO_4$, $CaCO_3$ and silica, etc.) present in saline solution reach supersaturation levels during the desalination process and precipitate out as scale deposits on membrane surfaces. In order to achieve constant flux, membrane surfaces have to be kept clean.

Two methods of approach can be taken 1) to chemically clean the membrane as often as required, which results in excessive shutdown time and higher operating costs, 2) the second approach is to pre-treat brackish water prior to its use as a feed to membrane plant for removal of fouling and scale forming constituents.

Generally, the following pre-treatment schemes are employed:

1) Surface Waters

   a) Coagulation, b) chlorination, c) sedimentation, and

   d) Deep bed media filtration

2) High Hardness Waters

   Lime or limesoda softening - pH reduction

3) Low Hardness Waters

   Zeolite softening, pH reduction

If organics are present in excess concentrations, activated carbon may be used as an additional filter.

In addition to the above, the feed water is treated with sulphuric acid for pH adjustment, when required, and sodium hexametaphosphate to minimize $CaSO_4$, iron and manganese hydroxides from forming scale deposits.

Brackish Water Desalting Costs

Variability in the quality of raw water, energy cost, and labor cost make it difficult to provide precise RO brackish water desalting costs. Presented below in tabular form are the costs extracted from several operating RO plants.

TYPICAL COST DATA FOR OPERATING RO PLANTS

LOCATION	CAPACITY (MGD)	CAPITAL $1000	COST $/GPD	WATER COST $/KGAL.
Greenfield, Iowa (11)	.15	94	.63	.77
Ocean Reef, Florida (11)	.93	460	.60	.90
Rotunda West, Florida (11)	.05	386	.77	1.25
Ft. Lupton, Colorado (10)	1.90	-	-	.60
Ft. Stockton, Colorado (10)	2.80	-	-	.66
Kehei, Hawaii (10)	-	-	-	.41
Arkansas City, Kansas (10)	5.75	-	-	.52
Artesia, New Mexico (10)	6.60	-	-	.48

Generalized Costs

Figures 3 through 6 show generalized curves for capital and operating costs of brackish water, RO plants as functions of plant capacity, feed water type and feed water salinity (11). These costs have to be updated by a factor of 1.45 ($\frac{1454}{1001}$) to bring the cost to July 1976 levels. One can use these cost figures to arrive at the first approximate cost for RO plants (both capital and operating costs).

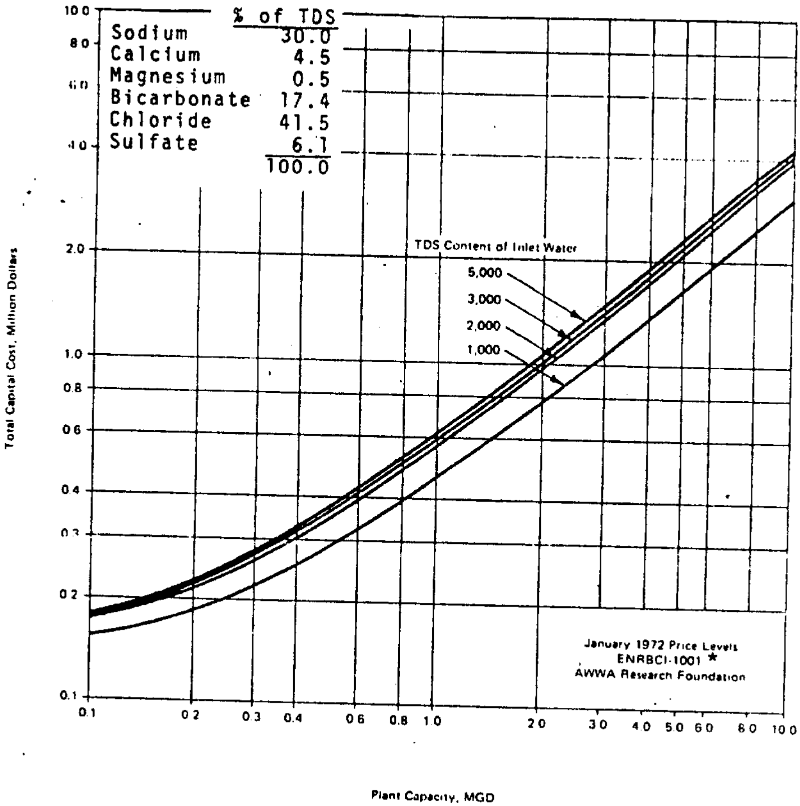
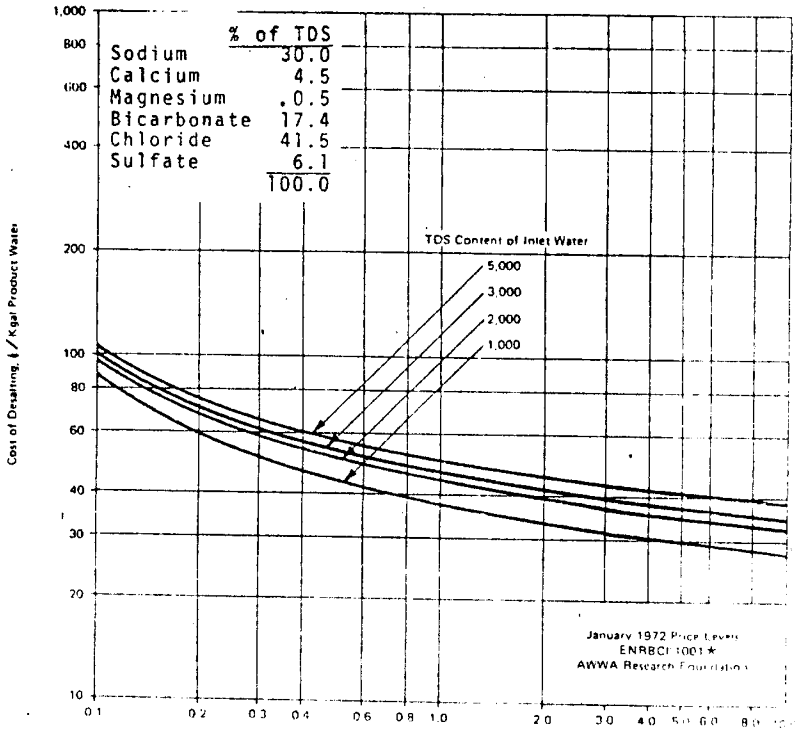


Figure 3 Capital Cost of Reverse Osmosis Plant (Sodium Chloride Water)

July 1976 ENRBCI = 1,454.



Plant Capacity MGD

Figure 4 Operating Cost of Reverse Osmosis Plant
(Sodium Chloride Water)

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* *July 1976 ENRBCI = 2,454.*

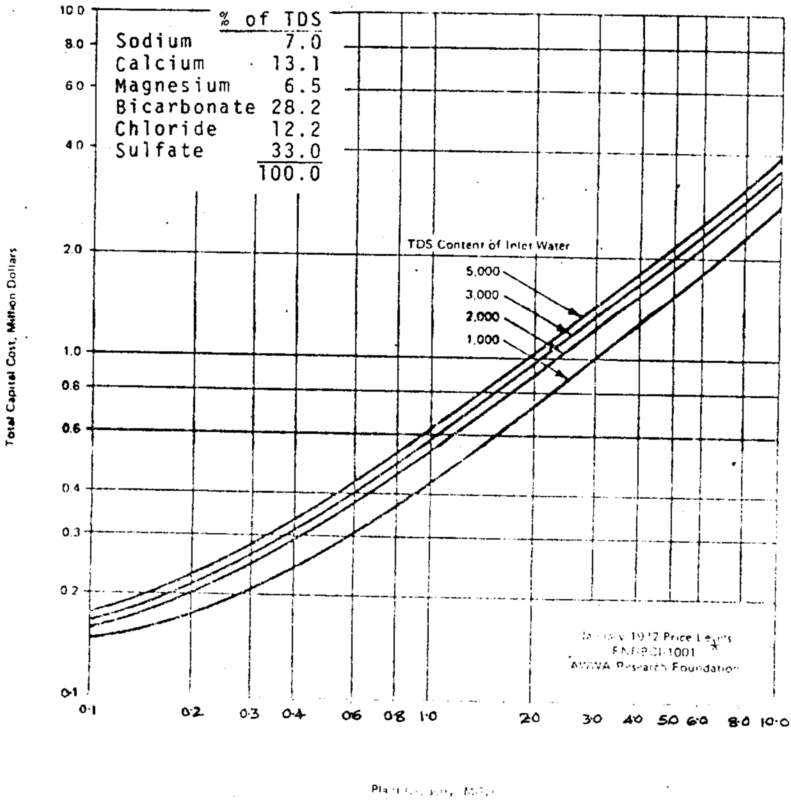


FIGURE 5 - Capital Cost of Reverse Osmosis Plant (Calcium Sulfate-Bicarbonate Water)

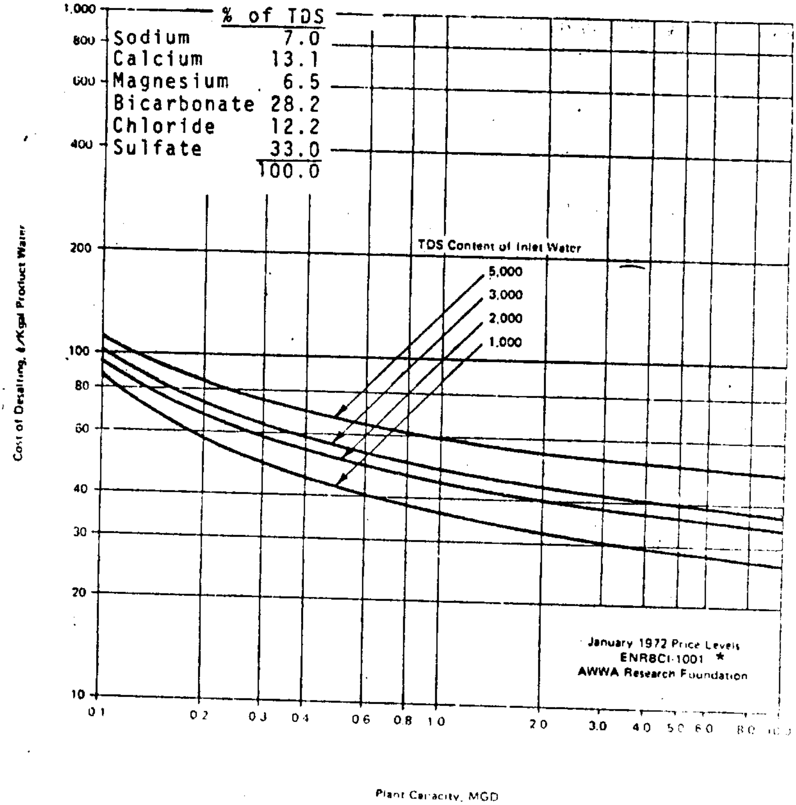


Figure 6 Operating Cost of Reverse Osmosis Plant (Calcium Sulfate-Bicarbonate Water)

*July 1976 ENRBCI = 1,454.

In Figure 7 the supplemental water requirement estimates up to the year 2036 for the three heavily populated counties (Palm Beach, Broward and Dade) are presented.

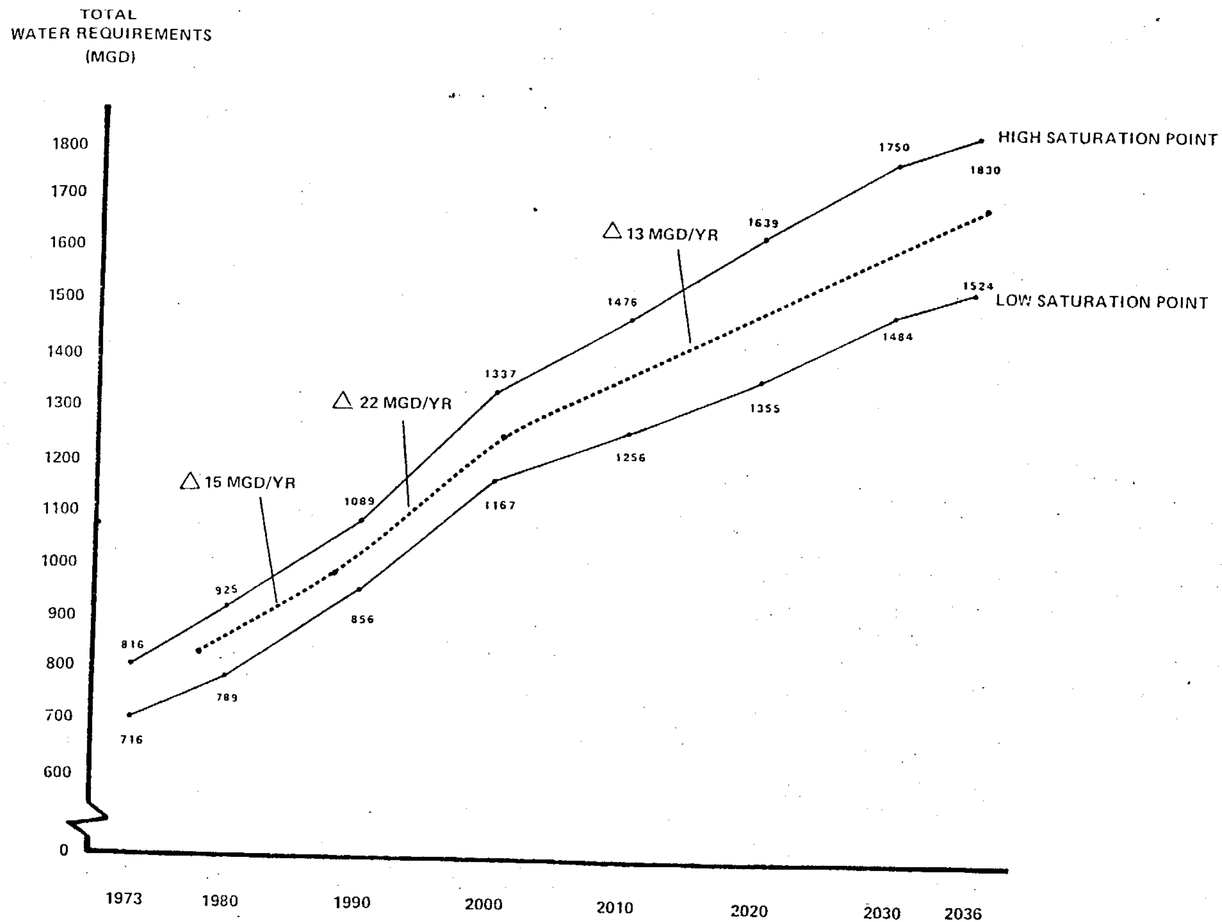
Two cases were examined to determine the feasibility of this desalt alternative. These are:

1) Supplementing water requirements for short term period (up to 1985-87).
2) Potential longer-range alternative applications for meeting water requirements.

Between 1977 and 1987, the estimated supplemental water requirement is around 15 MGD. If this alternative is chosen to meet the short term water requirements, and desalination plants built, there could be several advantages for municipal water suppliers, including:

1) The ability to meet more stringent drinking water quality standards without having to expand or increase current treatment plant capabilities.
2) Additional water quantities could be made available without having to expand the existing plant capacities, simply by drilling wells in the Floridan formation and desalting that quantity.
3) New supplies could be made available that are not subject to changing climatic conditions in terms of droughts, dry season supply defficiencies or salt water contamination.

A cost calculation is presented below (1000 TDS) for brackish water desalination plants of different sizes to meet the short term water requirements:



TOTAL
WATER REQUIREMENTS
(MGD)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
0
1973
1980
1990
2000
2010
2020
2030
2036
HIGH SATURATION POINT
LOW SATURATION POINT
△ 15 MGD/YR
△ 22 MGD/YR
△ 13 MGD/YR
816
925
1089
1337
1476
1639
1750
1830
716
789
856
1167
1256
1355
1484
1524

FIGURE 7

PLANT CAPACITY ($ 1000's)

	1 MGD	5 MGD	15 MGD
Construction Facilities	689	2,537	5,800
Total Construction +15% for Legal, Engineering and Contingencies	792	2,917	6,670
Total above +26% for distribution costs	998	8,675	8,404

The operation and maintenance costs would be:

PLANT CAPACITY ($ 1000's)

	1 MGD	5 MGD	15 MGD
Yearly Total	200	803	2,245
Interest and Amortization at 6 7/8% @ 50 years	49	181	413
Total Annual O&M Cost	249	984	2,685
Cost/1000 Gallons of Water	68¢	54¢	49¢

The replacement of RO membrane costs every three years is included in the operation and maintenance costs.

Present Cost of Potable Water in South Florida

The average base price per 1000 gallons of potable water in Palm Beach County is $1.05, in Broward County it is $1.36 and in Dade County $1.20 respectively. These costs include the pumping cost, treatment cost, transportation cost and the return on the investment set by the Public Service Commission.

However, most of the existing plants might not meet the "Safe Drinking Water Act" standards presently set by the Environmental Protection Agency. In order to meet the standards some utility companies might have to add other treatment units to their system, which in term will raise the base price of water.

As stated earlier, water produced from desalt plants will meet the EPA standards. Also, based on the survey of several operating RO plants, it is seen that the range of prices to produce 1000 gallons of water varied from $.48 to $1.25. This demonstrates that the poor quality brackish water which could not be used before, can now be desalted economically. A comparison with the present cost the consumers pay in south Florida shows that water can be tapped from the Floridan aquifer, desalted and sold to the customers at the same present rate.

RO Plant Design

In order to illustrate the elements involved in RO plant design a simple example is given. The design example concerns a schematic diagram for a spiral wound RO plant of 1.0 MGD to desalt a brackish water of 3000 mg/l TDS.

The parameters for the spiral wound membrane to be used in the calculation are as follows (RO manufacturer will supply these data):

Average element flux	16 gallons/ft.^{2}/day
Salt rejection	96 percent
product recovery	70 percent

Each element will contain 320 ft.^{2} of membrane.

Six membrane elements per pressure vessel.

Pump and motor efficiency - 70 percent.

Operating feed water pressure 400 psi

The brackish water was analyzed for chemical constituents and was found to be as follows:

Chemical Constituents	Concentration Mg/l
Ca	108
Mg	90
Na	951
K	9
Sr	3
Mn	1
HCO_3	10.7
Cl	1244
SO_4	940
NO_3	1
SiO_2	25
TDS	3394
Fe	.3
SS	5
Organics	1.0

Physical Properties

pH	5.5
Spec. Cond.	5605
Temp. C	24.5
Pressure loss	6 psi/vessel

Final Product:

Susp. Solids	0.0 mg/l

Before the RO Plant can be designed the feed water has to be pre-treated to remove the scale forming and fouling elements.

Pre-treatment

Suspended Solids: Can be removed either by 1) dual media filter (sand and antracite), 2) sand filter, or 3) coagulation. However, filtering should be selected based on the suspended particle. The suspended solids have to be analyzed for particle size.

Iron: If present in excess of 0.2 mg/l, it has to be removed. Membrane will foul due to iron and manganese.

Organic and Substances: Causes membrane fouling. Use activated charcoal.

Bicarbonate: Bicarbonate concentration if less than 100 mg/l is acceptable. Otherwise, use acid.

Sulfate Removal: Solubility limit of Ca + SO_4 is 1600 mg/l. If sodium hexametaphosphate is used up to 3200 mg/l of sulfate can be removed.

pH Check: pH of the feed water cannot be higher than 5.5 for spiral wound membranes. If it is higher, sulfuric acid is added to lower the pH to the 5.5 level.

Silica: If present in concentration of 100-140 mg/l silica will precipitate. Use coagulation and filtration.

Once the pre-treatment of the feed water is taken care of, the design of the RO plant procedes as follows:

We will calculate the following in the design:

1) Product water flow/day.

2) Brine concentration mg/l

3) Feed flow required/day

4) Product Water concentration mg/l

5) Energy requirements

6) KWH/1000 gallons of product water

These basic equations are used in the calculations and they are:

$$F_{feed} = F_{prod} + F_{rej}$$

$$C_{feed} = F_{prod} \times C_{prod} + F_{rej} \times C_{rej}$$

$$\text{Recovery} = \frac{F_{prod}}{F_{feed}}$$

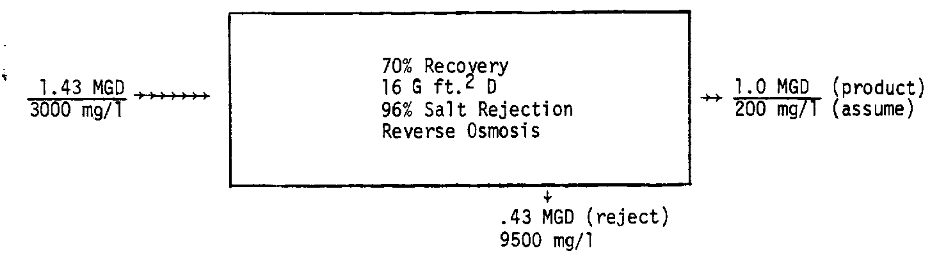
Where,

F = Flow

C = Concentration

rej = reject

prod = product flow



<u>Feed Flow Required</u>

1) $$\frac{0.7}{1} = \frac{1.0}{F_{feed}} = \frac{1.0}{0.7} = 1.43 \text{ MGD (993 GPM)}$$

<u>Brine Concentration</u>

Assume 200 mg/l TDS in the product water

2) $$1.43 \times 3000 = 1.0 \times 200 + 0.43 \times C_{rej}$$

$$C_{rej} = 9500 \text{ mg/l}$$

To determine exactly what kind of product flow concentration we will have:

$$C\,avg = \frac{Cfeed \cdot Ffeed + Crej \cdot Frej}{Ffeed + Frej}$$

$$= 4{,}500 \text{ mg/l}$$

$$Cprod = 4{,}500\,(1 - Crej)$$

$$= 180 \text{ mg/l}$$

Choose around 185 mg/l as the product water concentration and iterate until the assumed concentration equals the calculated one.

Elements Required

Product water - 1,000,000 gallons/day

Avg. flux - 16 gallons/ft.^{2}/day

$$\text{Membrane required} = \frac{1{,}000{,}000}{16} = 62{,}500 \text{ ft.}^2$$

Each element will contain 320 ft.^{2} of membrane

$$\text{No. of elements required} = \frac{62{,}500}{320} = 195$$

$$\frac{195}{3} = 33 \text{ vessels}$$

Vessels can be arranged in 2:1 configuration as follows:

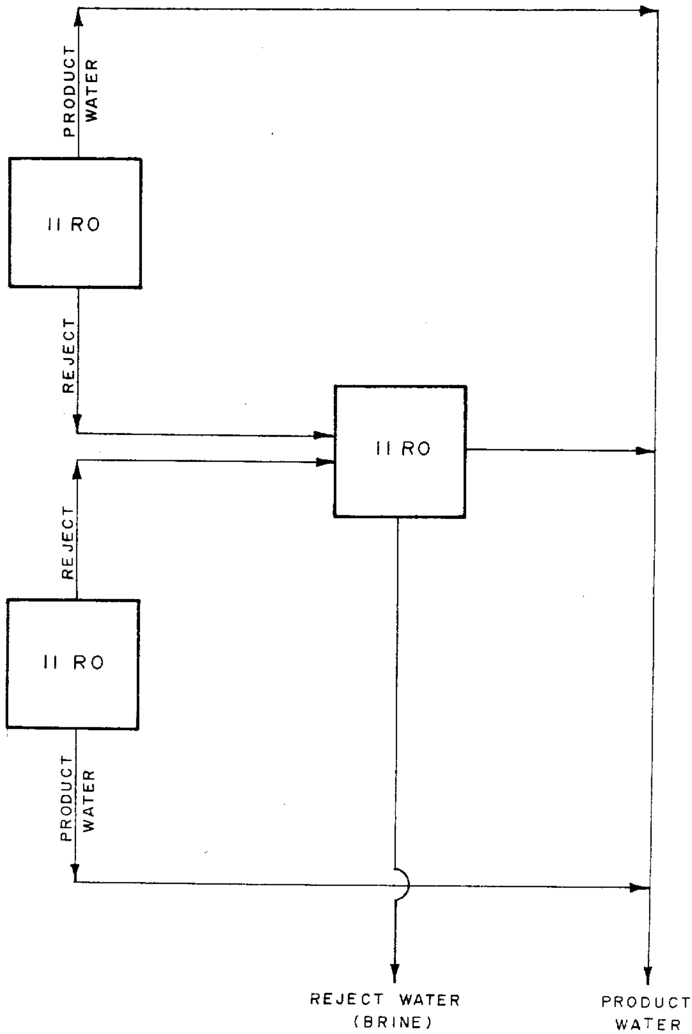


Figure 8 2:1 RO PLANT LAYOUT

Energy Required

1 HP = 33,000 ft.lb./min.

$$\text{Flow} = \frac{1.43 \times 10^6}{1,440} = 992 \text{ gallons/min.}$$

$$\text{HP} = \frac{992 \frac{\text{gallons}}{\text{min.}} \times 8.34 \frac{\text{lb.}}{\text{gal.}} \times 2.31 \text{ lb.} \times 400 \text{ psi}}{33,000}$$

THP = 231.7

$$\text{HP} = \frac{231.7}{.70} = \underline{\underline{331}}$$

KWH = 331 X .745 = $\underline{\underline{246.6}}$ KWH

KWH/1000 gallons

Flow/Hr. = 42,000 gallons

$$\text{KWH/1000 gallons} = \frac{246.6}{42} = \underline{\underline{5.9}}$$

SUMMARY

One of the alternatives being studied by the South Florida Water Management District in meeting the future water requirements of south Florida is by desalting the vast quantity of brackish water contained in the Floridan aquifer. Brackish water desalination by reverse osmosis process has reached commercial scale.

The total water cost as reported in the literature to produce 1000 gallons of product water is reported. Additionally, the general construction and the OMR costs updated to July 1976 figures are presented.

The cost to produce 1000 gallons of product water from RO plants (1,5 & 15 MGD capacity) is calculated and compared against the base price of 1000 gallons of water presently being paid by the consumers in the lower east coast area. Comparison shows that RO is already feasible for south Florida conditions. Additionally RO is superior to coagulation, chlorination or active carbon in removing pollutants from groundwater. Finally, a simple calculation on the design of a 1 MGD plant using spiral wound membrane is included.

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and a
Happy New Year!

INTERNATIONAL DESALINATION AND ENVIRONMENTAL ASSOCIATION

GROWTH OF DESALT PLANTS IN SOUTHWEST FLORIDA

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"On an average annual basis, southwest Florida receives 53 inches of rainfall. Still, southwest Florida presently is one of the largest users of desalted water in the nation. Approximately 90 percent of the desalted water presently being used is for potable purposes."

Introduction

The favorable tropical climate of south Florida has been the biggest attraction for rapid and hard to control growth. In the past, southeast Florida attracted the major portion of this growth; however, the growth pattern recently has shifted to Florida's west coast.

Six counties (Lee, Hendry, Charlotte, Sarasota, Glades and Collier) constitute what is known as the Southwest Florida Region. The population of this region increased from 71,255 in the year 1950 to an astonishing 458,053 in 1976 (11). Almost 97 percent of the population resides along the coastal areas.

In the past, no water management plan existed to supply water to the ever-increasing population of the area. However, the Florida Water Resources Act of 1972, Chapter 373, has mandated that the state prepare a Water Use and Supply Plan. The responsibility for this task has been delegated to the five Water Management Districts. As can be seen from the map, all the area except Sarasota County and half of Charlotte County, lies within the jurisdiction of the South Florida Management District (Map 1).

The District is presently actively engaged in preparing a Water Use and Supply Development Plan for the region. One of the alternatives being studied in great detail is desalination. More and more desalination plants, both large and small, are being built to supply potable water on a continuous basis to the inhabitants of the area.

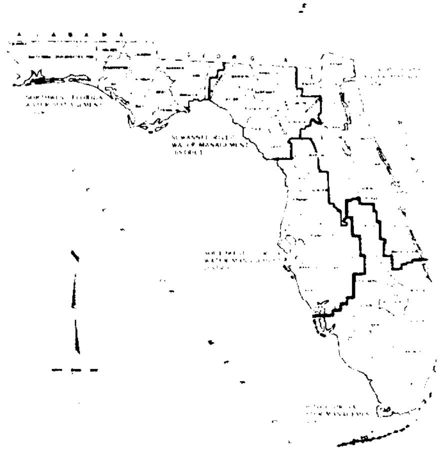

FIGURE 1
WATER MANAGEMENT DISTRICTS OF FLORIDA

This paper will briefly highlight the reasons behind the growth of desalination typical system operation of desalination plants, and finally, a cost comparison of producing water from a line softening plant vs. a reverse osmosis plant as applied to the southwest Florida region.

WATER RESOURCES OF THE REGION

Surface Water

The surface water resources of the region necessary to meet the ever increasing population's water requirements consists almost entirely of the Caloosahatchee

River. The river is presently tapped by Lee County and the city of Fort Myers for potable water supply purposes. The Caloosahatchee River would normally be expected to satisfy at least the future demands of Lee County far into the future; however, the river is limited in its ability to supply the area because of saltwater intrusion during the dry season. The chloride content of the water usually exceeds the allowable limits acceptable for potable water supplies and conventional treatment techniques. Additionally, in recent years algae blooms have been reported during the dry season (9).

Furthermore, a recent report released by the Florida Department of Environmental Regulation shows the trihalomethane (THM is a class of chemical that includes the carcinogen chloroform) content of the potable water supply exceeds the proposed limit set by the Federal EPA. If EPA imposes and enforces the THM standard, then the Lee County utility plant will have to implement expensive changes to comply (10).

Groundwater

The shallow water table aquifer and the Floridan aquifer are the two principal local water resources of the region. The shallow water table aquifer serves as a limited local freshwater resource of the region. To date, the shallow aquifer system has not been studied in detail concerning its water yield and other properties. Presently, for the Water Use and Water Supply Plan of the area, the District is undertaking detailed groundwater studies, including aquifer pump tests to determine the yield from this aquifer system.

One of the largest shallow aquifer users of this region is the city of Naples. The potable water of the city is found to contain THM beyond the federal EPA standard (10). This water will require further treatment if the EPA imposes the THM standard.

Floridan Aquifer

A vast amount of water exists in the Floridan aquifer system of the region. This aquifer system is less commonly used because of its high mineral content (>500 TDS), which requires desalination to meet the Public Health Standards for potable water. All the desalt plants except Pelican Bay receive their feed water from this source.

DESALINATION PLANTS IN SOUTHWEST FLORIDA AND THE KEYS

A report published by the Office of Water Research and Technology (7) shows that 11.5 million gallons per day of desalting capacity existed in this region in the year 1975. This desalting capacity has been increased to 16.25 million gallons per day as of November 1978, and a further increase of 5.2 million gallons per day (3,8) is anticipated in the near future. (See Table 1 and Map 2).

Table 1. Desalt Plants in Southwest Florida and the Keys

Plant	Type	Capacity(GPD)
1. Key West	MSF	2,500,000
2. Ocean Reef (Key Largo)	R.O.	930,000
3. Sanibel Island	E.D.	1,500,000
4 Sarasota Siesta Key	E.D.	2,000,000
5. Sorrento Shores	E.D.	70,000
6. Rotonda West	R.O.	500,000 (Expanding to 1,000,000)
7. Rock Harbor	R.O.	1,000,000
8. Cape Coral	R.O.	3,000,000
9. Key Largo	R.O.	1,000,000
10. City of Venice	R.O.	1,000,000
11. Palm Bay	R.O.	120,000
12. Ponce Inlet	R.O.	1,000,000
13. Punta Gorda	R.O.	95,000
14. Sarasota (Ramar Dooley Const.)	R.O.	100,000
15 Sarasota (South Bay)	R.O.	100,000
16. Sarasota	R.O.	34,000
17 Charlotte Harbor	R.O.	250,000
18 Punta Gorda	R.O.	150,000
19. Sorrento Shores (Nocoma)	R.O.	180,000
20. Captiva	R.O.	17,000
21. Bonita Springs	R.O.	48,000
22. Fort Myers	R.O.	20,000
23 Sarasota	R.O.	10,000
24 Bonita Springs	R.O.	24,000
25. Charlotte Harbor	R.O.	90,000 (2 EPA Plants)

SOUTHWEST FLORIDA
DESALT PLANT LOCATIONS

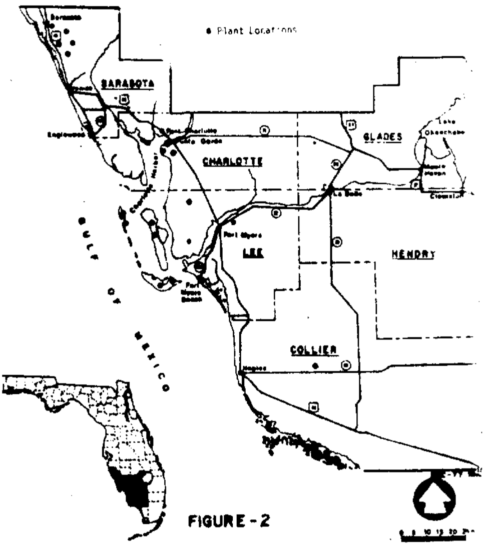

FIGURE - 2

26. Punta Gorda	R.O.	26,000
27. Pelican Bay	R.O.	500,000
Total		16,750,000

Proposed

1. City of Sarasota	R.O.	4,500,000
2. Sanibel Island	R.O.	500,000
3. Everglades City	R.O.	200,000
Total		5,200,000

It is interesting to note that all the desalination plants except Key West are either Electrodialysis or Reverse Osmosis plants. Even the Key West plant which was originally designed for sea water desalination uses brackish water as feed water, which shows the abundancy of brackish water in the region.

The United States Geological Survey report (11) indicates that 64.5 million gallons of water is used presently for potable uses on a daily basis. Out of that total 16.75 million gallons (or 25 percent of the total potable water) is desalted water. Additionally, more desalination plants are underway to increase this percentage.

Because of the vast amounts of mineralized water that are available in the Floridan aquifer system and because of the proposed EPA safe drinking water standards, this region will probably have more and more desalt plants in the future.

SYSTEM OPERATION OF DESALINATION PLANTS IN SOUTHWEST FLORIDA

Buros (1) recently made a survey of some of the typical brackish water membrane desalination plants (both Electrodialysis and Reverse Osmosis) of the region (Table 2). As can be seen from the table, desalination plant sizes varied from 140,000 to 3,000,000 gallons per day. The product water recovery percent varied from 47 to 82 percent. The power requirements varied from 7.0 to 12.5 KWH/Kgal of product water, including the power required to pump feed water from the deep Floridan aquifer wells. With the present electricity cost of $0.358, the power cost to produce 1000 gallons of product water varied from 25¢ to 44.7¢. Table 2 also shows that Electrodialysis membrane had to be changed quite often; however, no sulphuric acid was needed in the ED plants.

It has been reported by various water agencies including the federal EPA that desalination techniques, due to high costs, power consumption and unreliable fossil fuel, are not an acceptable alternative means to supply water (2). It is interesting to note, however, that even the EPA has two

45,000 gallon R.O. plants at Charlotte Harbor to test what kind of chemicals R.O. membranes can remove from the potable water (Table 1).

ECONOMICS OF DESALINATION

In order to familiarize the readers with the overall cost of both the conventional and the desalt method of water treatment, a cost comparison of Cape Coral's lime softening water production cost is made against the newly installed R.O. plant to produce 1000 gallons of potable water.

Presented in Tables 3 and 4 are the two actual production cost figures for six months of operation of the two water treatment plants. Table 3 shows that the total monthly cost to produce 1000 gallons of product water from the R.O. plant varied from 56¢ to 66¢, the full operational average being 52.7¢. During the same period, the lime softening plant (Table 4) produced water at a price range of 32¢ to 41¢, the average being 37¢/1000 gallons. The R.O. plant was constructed by the city as more water could not be produced from the shallow water table aquifers. Additionally, as stated earlier, the potable water supply of the region (both surface and ground water), has shown high limits of THM beyond the EPA standard. Groundwater is also found to have higher salinity levels than allowable for potable uses in some areas, and can be treated only by desalt techniques.

Assume that the potable water produced from the lime softening plant has to be treated for THM also. As per the Miami-Dade Water and Sewer Authority (10), one way of removing THM is by use of activated carbon. Further, if activated charcoal filtration is required, water rates will go up by more than 50%. Assuming that Cape Coral incorporates charcoal filtration for the water obtained from the lime softening plant, then using the cost as estimated by the Miami-Dade Water and Sewer Authority, the cost to produce 1000 gallons of water will increase to 56¢. This figure is higher than the present cost of producing 1000 gallons of better quality product water from the R.O. plant (52.7¢).

It is anticipated that sooner or later most of the water plants have to add charcoal filtration. If that happens, then as shown above, R.O. method of water treatment is comparable to, if not cheaper than, the conventional method with additional charcoal filtration.

The present water price customers pay in the region per 1000 gallons of delivered water is presented below. The cost is calculated assuming that an average family uses 7,500 gallons of water per month.

Utility	Delivered Price/1000 Gal.
Lee County	$1.86
Lehigh Acres	$1.51
Cape Coral	$1.60
Bonita Springs	$1.88
Sanibel Island	$2.40

Included in the above prices are transmission, administration, bond obligation and other costs. The above table points out one thing, however; that no matter whether the potable water is treated through conventional techniques or desalt techniques, customers pay essentially the same price.

Conclusions

Southwest Florida receives 53 inches of rainfall per year, which by comparison with the western United States standards, is a water rich area. However, there are no surface water reservoirs to impound this water. The only surface water body of the area is Lake Okeechobee which feeds into the Caloosahatchee River. The river is tapped by the City of Fort Myers and Lee County. Higher than allowable chloride content for patable uses during dry seasons and occasional algae blooms must be controlled before the river can be depended upon with a high reliability factor for future potable water requirements of the area. Additionally, the recent finding of THM in the potable water might necessitate further treatment of the water, especially by activated charcoal filtration, which undoubtedly will raise the production costs. If that

TABLE 2
Summary of Operating Data of Seven Desalination Facilities in Florida

Plant location	Sorrento Shores	Rotonda West	City of Venice	Cape Coral	Sanibel Island[a]	Sorrento Shores	Sanibel Island
Design capacity (kgal/day)	340	500	1,000	3,000	550	70	2,100
Began operation	1975	1977	1975	1977	1979	1973	1973
Process	RO	RO	RO	RO	RO	[illegible]	ED
Type membrane	Spiral	HF	HF	HF	Spiral	Flat	Flat
Number of membrane elements	43	66	96	132	120	2 stacks	24 stacks
Hydraulic data[b]							
Feed (kgal/day)	300	860	1,820	1,960	733	140	1,260
Product (kgal/day)	140	430	1,000	1,260	550	70	1,030
Percent recovery	47	50	55	64	75	50	82
Quality data--TDS							
Feed (mg/l)	3,900[c]	8,1[illegible]	2,000	1,334	2,000	2,000	2,700
Product (mg/l)	266[c]	245	190	75	410	1,000	450
Percent salt rejection	92	96	91	95	94	50	81
Power consumed[d]							
kWhr/kgal product	12.5[e]	15.7[e]	10	11.7[e]	7.0	10	9.9
kWhr/1,000 mg/l TDS removed/kgal product	3.8[e]	2.0[e]	5.5	9.2[e]	1.1	10	4.4
Expendables consumed							
Sulfuric acid (lb/kgal product)	2.5	1.3	1.45	1.56	1.5	--	-
Sodium hexametaphosphate (lb/kgal product)	0.1	0.05	0.11	0.05	0.04	-	
Sodium hydroxide (lb/kgal product)	0.75[f]	0.04	--[g]	0.07	0.15	--	0.68[f]
Chlorine (lb/kgal product)[h]	--	--	--	--	--	0.15	0.12
Activated carbon (ft³/kgal product)	--	--	--	--	--	0.003	0.002
Membranes replaced (each)	--[i]	31/6 yr[j]	1/3 yr	0/1.5 yr		144/yr	1,552/yr
Electrodes replaced (each)	--	-	--	--	--	0.0003	0.0001
Cartridge filters (cartridge/kgal product)	0.00015	0.0066	0.0036	0.002	--	0.07	0.02
Labor (O&M)(man-hour/kgal product)	0.65	0.01	0.01	0.07	0.05	0.08	0.05

Notes. 1 Summary based on data for all or part of 1977 and/or 1978. Reliability of data varies from plant to plant.
2 RO = reverse osmosis, ED = electrodialysis, EDR = electrodialysis with phase reversal, HF = hollow fiber

[a] Facility to be constructed in 1979. Data based on supplier's guarantee.
[b] All plants do not have a 100% load factor
[c] Conductivity measurement (μmhos/cm²)
[d] Equipment included in this figure varies
[e] Includes supply wells
[f] Soda ash
[g] pH adjustment by combining with effluent of adjacent lime softening plant
[h] Prechlorination for ED
[i] Twenty four membranes replaced by supplier due to problems caused by defective flowmeter
[j] Includes eight membranes being used at reduced capacity

TABLE 3.

ACTUAL OPERATING COSTS FOR
FIRST SIX MONTHS OF R.O. OPERATION (CAPE CORAL)

	April	May	June	July	August	Sept	Average (Cost/1,000)
Total Flow (Million gal.)	55.7	58	41	36	33	28	42
Average Daily Flow (MGD)	1.86	1.8	1.4	1.2	1.1	0.9	1.4
Chemical Costs							
Chlorine	$266	[illegible]	$120	$117	$103	$95	$127
NaOH	-	-	-	60	10	8	13
NaHEX	2,610	6,380	3,969*	660	82?	602	763
H_2SO_4	1,673	1,7[illegible]	1,230	1,261	1,089	710	1,293
Total Chemical	$ 4,469*	$8,[illegible]*	$ 5,319*	$ 2,298	$ 2,026	$ 1,415	$ 2,205 (5.3¢)
Power Costs	13,811	14,924*	12,261	11,332	10,507	8,597**	12,906 (30.7¢)
Labor (Salary +37% O.H.)	12,593	9,283*	9,453*	6,954	7,382	6,495	7,000* (16.7¢)
Total Costs	$30,8[illegible]*	$32,443*	$27,033*	$20,585	$20,116	$16,507	$22,111
Cost/1,000 Gal	66¢*	[illegible]	66¢	57¢	61¢	59¢	52.7¢
Cost/1,000 Gal, assuming 4.? MGD output and labor constant							41.2¢

* These figures were abnormally high during start-up period. The averages were therefore extrapolated from the last three months.

** September's power cost was estimated.

TABLE 4. ACTUAL OPERATING COSTS FOR CORRESPONDING SIX MONTHS OF LIME PLANT OPERATION (CAPE CORAL)

LIME PLANT

	April	May	June	July	Aug.	Sept.	Average
Flow	N/A	38 MG	30 MG	33 MG	38 MG	42 MG	36.2 MG
ADF		1.2	1.0	1.1	1.2	1.4	1.18
Chemical Costs		$ 2,109	$ 1,638	$ 1,852	$ 1,933	$ 1,940	$ 1,840
Power		$ 4,812	$ 4,292	$ 4,449	$ 4,708	$ 4,800 (est)	$ 4,610
Labor		$ 7,403	$ 6,080	$ 7,060	$ 7,969	$ 6,709	$ 6,844
Total		$12,324	$ 11,[illegible]	$13,391	$14,510	$13,449	$13,294
Cost/1,000		$ 0.35	$ 0.[illegible]	$ 0.41	$ 0.38	$ 0.32	$ 0.37

happens, then the price of water from a R.O. plant will be competitive, if not cheaper.

The local groundwater resources of the region are not known in detail as yet. Studies are underway to determine this potential. Even the shallow water table aquifer in some areas of the region is found to have salinity levels beyond Public Health Standard limits, and are being treated by desalt techniques. Additionally, in other areas of the region, potable water from the non-saline shallow aquifer is found to contain THM beyond the EPA standards which might require further treatment and raising of the water price.

Based on the above reasoning, it can be stated that desalination techniques are already a viable alternative in supplying a major portion (25%) of the potable water of the southwest Florida region. In the future, if activated charcoal filtration is required, and as shown earlier that reverse osmosis cost is comparable if not cheaper than lime softening plus activated charcoal filtration, it can be predicted that more and more desalination plants, in lieu of or as additions to conventional water treatment plants, will be constructed in this region.

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VIWAPA AWAITS COMPTROLLER

Any further action on the purchase of desalination plants by the Virgin Islands Water and Power Authority (VIWAPA) awaits the completion of the Virgin Islands' Comptroller's report. OWRT is lending some assistance to the Comptroller's Office with the report and it should be out "soon." After the report, the Government of the Virgin Islands will need to act regarding financing. Although there was some turnover in the Virgin Islands Legislature in the election in November, the governor, Juan Luis, retained his post which should minimize the confusion that can occur when the government changes hands.

Quick action may be difficult if the report drags too much into December as the Christmas and New Year's holidays create a great lull in governmental functions from about December 15th though January 6th. The latter day is Three Kings Day and marks the carnival on the island of St. Croix. Between those dates there are about four government holidays, a lot of good spirit, and a poor time to do business.

DESALINATION ACTIVITIES IN FLORIDA

The need for desalination capabilities in Florida, and the growth of these systems can be directly attributed to the saltwater intrusion problems that are in evidence along much of the state's coastline where most of the population of over 8½ million live.

Florida receives more rainfall (about 53 inches per year statewide) than any other state in the continental U.S. except Louisiana. Unfortunately this rainfall does not occur uniformly over any given year, or series of years. For the penninsula of Florida there is a strong seasonality, where 60% of the rainfall occurs during the "wet" season (from June to September). A "dry" season occurs each year, generally from December through May.

It is during these "dry" seasons that saltwater intrusion becomes limiting with respect to the amounts of fresh water that can be withdrawn for use for domestic, agricultural and industrial purposes. Not only are coastal aquifers affected, but also coastal rivers where flow has been dimenished, and drainage and flood control canals which open to tidewater. Saltwater intrusion is also a problem in interior areas due to ancient deposits of saltwater which underlie the entire state at varying depths.

STATEWIDE DISTRIBUTION & USE

Where control of saltwater intrusion in groundwater cannot be achieved by maintaining sufficient freshwater hydrologic heads the use of desalination plants has been effectively implemented. Figure 1 shows the development of these plants, by county. 16 of Florida's 67 counties have operating plants, all but two being in coastal areas. There are a total of 67 plants in operation, producing 18.1 MGD of water. About 94% of this production is for domestic use, with the remainder serving various industrial and power needs.

PLANT CAPACITIES & TYPES

Of the 67 desalination plants currently in operation, about 72% (48) are designed to produce under 100,000 gallons per day (see Figure 2). There are 14 producing plants between 100,000 and one million gallons per day. The largest of the five plants producing over 1 MGD, is the 3 MGD potable water supply for Cape Coral in southwest Florida (Lee County).

All the plants in Florida use the RO process except for the 2.6 MGD Flash Distillation plant in Key West and the 2.1 MGD Electrodialysis (ED) plant on Sanibel Island (Lee County).

OPERATIONAL CHRONOLOGY

The first significant desalination plant in Florida was the 2.6 MGD Flash distillation unit on Key West, at the tip of the Florida Keys, which started operation in 1967 (see Figure 3). Other plants were slow in developing until after a moderate drought in 1970-71 increased the public's awareness about saltwater intrusion-dry period relationships and the resultant water shortage potentials. 38 new plants were put into operation between 1972 and 1975.

The problems which beset the Florida Keys plant did much to "turn off" interest in desalination and still remain a constraint in the minds of many consultants and the public to this day. This is despite the little known fact that the plant, originally designed to handle seawater, was made to operate with brackish aquifer source water which caused most of the initial and subsequent tube fouling problems.

PRODUCED WATER COSTS

It is generally difficult to present a fair comparison of water use economics since the final delivered costs depend on the physical area served, pre-and post-treatment requirements, method of charging customers, etc. When all these factors are put on the most comparable basis possible, and averaged as appropriate, the price customers pay (in southwest Florida for example) for water can be shown to be:

UTILITY	TYPE	DELIVERED PRICE/1000 GALLONS (1977)
Lehigh Acres	Conventional	$1.51
Cape Coral	R.O.	1.61
Lee County	Conventional	1.86
Bonita Springs	Conventional	1.88
Sanibel Island	R.O.	2.40

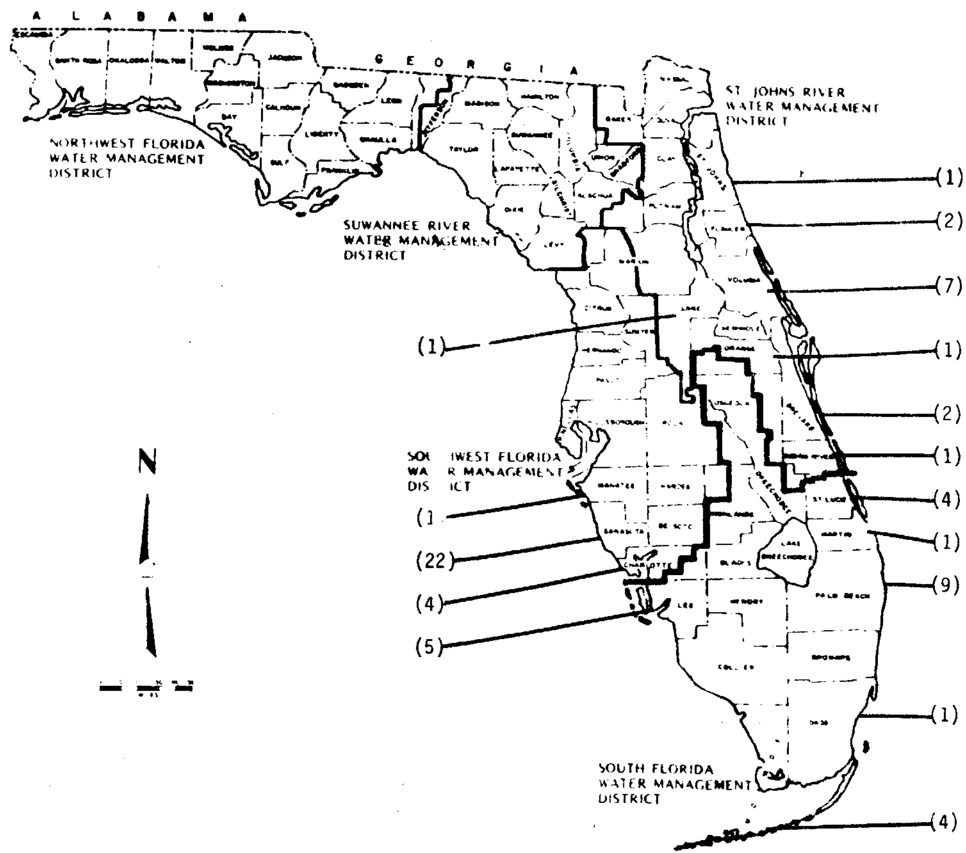
The above comparison includes all costs for treatment and delivery, such as chemicals, debt retirement and energy. While energy expenses for R.O. plants is higher (on a percentage of operating expense basis) than for a conventional plant, its effect is not as pronounced in terms of delivered price.

It can be concluded that for specific desalination applications in Florida, where source water of relatively high salt contents are the only available basic water supply, these systems are cost competitive and within the means of the using public.

FUTURE DESALINATION POTENTIALS IN FLORIDA

The South Florida Water Management District (as outlined in Figure 1) contains over 40% of Florida's population and 36% of the operating desalination plants. This District has supported the development of desalination capabilities where the need is evidenced. This has included holding seminars for consultants and utility personnel so they will know how to specify the process involved, work with system designs and keep track of future capabilities, materials and systems. The District in its water use planning is also considering larger scale desalination potentials which might be applied on a regional basis, such as those shown in Figure 4.

As Florida continues to grow rapidly and potable water supplies are strained in coastal areas, the future potential for desalination is great. This is true considering new water quality treatment requirements that may be applied which will further tend to offset the energy differential between conventional and desalination systems.



(NUMBER OF DESALINATION PLANTS PER COUNTY)

WATER MANAGEMENT DISTRICTS OF FLORIDA

FIGURE 1.

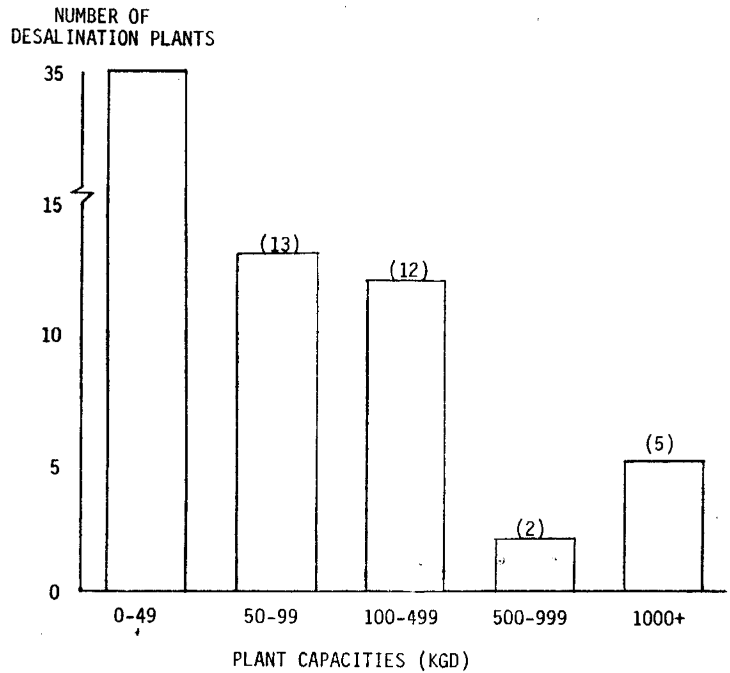
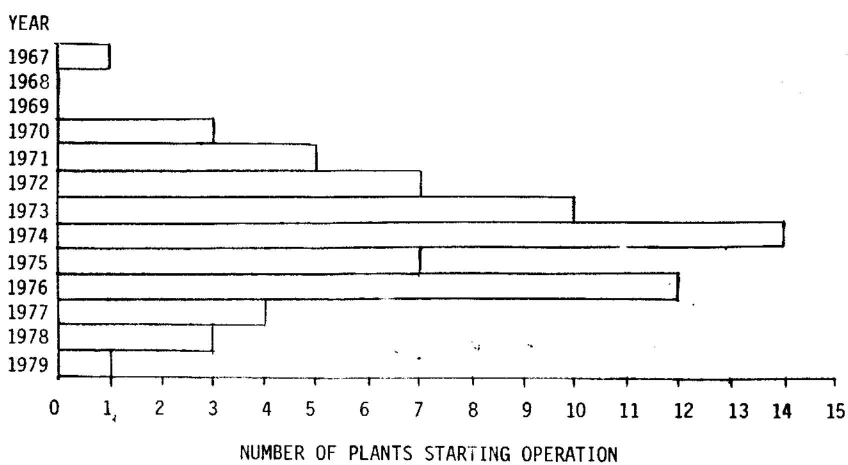

NUMBER OF
DESALINATION PLANTS
35
15
10
5
0
(13)
(12)
(2)
(5)
0-49
50-99
100-499
500-999
1000+
PLANT CAPACITIES (KGD)

FIGURE 2.


YEAR
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
0
1
2
3
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5
6
7
8
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10
11
12
13
14
15
NUMBER OF PLANTS STARTING OPERATION

FIGURE 3.

FUTURE DESALINATION POSSIBILITIES

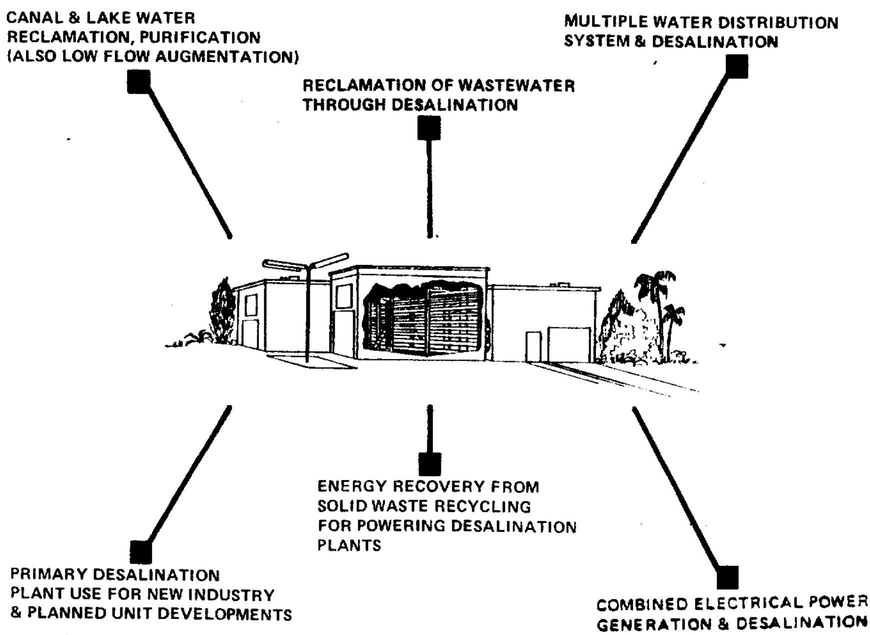

FIGURE 4.

POTENTIAL FUTURE ROLES FOR LARGE-SCALE DEMINERALIZATION IN SOUTH FLORIDA

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ABSTRACT

Future planning to assure adequate and consistent water supplies for south Florida has progressed to the point where a range of alternative systems has now been defined and partially evaluated. Conventional approaches to retain surface water supplies (such as in Lake Okeechobee and the Water Conservation Areas) have potential, as well as more advanced concepts involving demineralization, deep aquifer storage and various degrees of wastewater reuse.

It is feasible, based on planning and demonstrations due to date (e.g. for the Yuma desalt facility) to consider similar large scale desalting operations in south Florida. The high water quality standards in Florida will require that the broadest range of alternative treatment techniques be assessed to provide for maximum water resource protection at the minimum cost.

For example, Lake Okeechobee, the second largest freshwater lake in the U. S. is impacted by numerous inflows which carry large amounts of nutrients such as nitrogen and phosphorus. The reduction of these nutrients is a high priority goal of managing south Florida's water resources in the future.

The placement of a large scale desalination plant, which has demonstrated the capability to remove these types of nutrients, at a strategic point prior to the water's input to Lake Okeechobee could provide a reduction potential which would allow the various standards to be met.

In addition, multiple or dual use of water produced by such a plant could serve surrounding agricultural areas and nearby urbanizing communities with both potable and reduced - salt agricultural water supplies.

This concept is investigated and reported in this paper, along with other potential considerations for larger scale applications in south Florida.

INTRODUCTION

"Water seems to be available in the wrong place, at the wrong time, and in the wrong quality."

<u>United Nations Report</u>

South Florida in a sense, is a water rich area receiving 55-60 inches of rain on a yearly average, with only a small percentage of this water consumed by man's activities.

When the region receives the average rainfall every year, no water problems occur. Lake Okeechobee and the conservation areas have the capability of storing surface runoff and the backpumped water from the Everglades Agricultural Areas; and also supplying water to the present population of the most heavily populated areas (Dade, Broward and Palm Beach counties) for some time into the future. However, with the increasing population and the vagaries of nature which cause periods of below average rainfall (during the 1970-71 drought only 38 inches was recorded), the South Florida Water Management District is undertaking the development of a water use and supply development plan for the region to meet future fresh water requirements under a wide variety of growth conditions.

The water use plan for the lower east coast of Florida addresses 14 alternatives to meet the future water requirements of the region. These alternatives are:

1) Conservation
2) Regulation
3) Wellfield Development
4) Backpumping of Storm Water
5) Forward Pumping
6) Additional Water Storage in Lake Okeechobee
7) Desalination of Brackish Water
8) Deep Aquifer Storage
9) Reuse of wastewater for non-potable uses
10) Weather Modification
11) Desalination of Sea Water
12) Additional Surface Water Storage Areas
13) Evaporation Suppression
14) Water Importation

As can be seen from the above, the alternatives that were evaluated consist of both structural and non-structural approaches to retain surface water supplies (such as in Lake Okeechobee, the conservation areas, and the creation of new additional surface water storage areas), as well as more advanced concepts involving demineralization of both brackish and sea water, deep aquifer storage and various degrees of wastewater reuse.

The remaining part of this paper is devoted to potential future role for large-scale demineralization in south Florida.

DESALTING EXPERIENCE

Two reports (refs. 10 and 11) published by the Office of Water Research and Technology show the amounts of desalting capacity in Florida. In the year 1975, the report shows approximately 331 desalting plants in the U. S. with a total desalting capacity of 68.7 MGD. By the year 1977 the plants and the desalting capacities increased to 481 and about 100 MGD, respectively. (These figures are for plants with capacities over 25,000 GPD.)

Table 1 below presents a few selected principal locations of U. S. desalting plants, numbers and capacities (MGD) for the year 1975 and 1977.

TABLE 1

Principle Locations of U. S. Desalting Plants

Location	1975 Number	1975 Capacity (MGD)	1977 Number	1977 Capacity (MGD)
Virgin Islands	15	15.3	16	15.32
Florida	32	11.5	47	16.83
Texas	38	8.2	54	12.88
California	54	7.5	92	16.78

The above table shows that Florida is still the largest desalt water user in the nation, even though the average annual rainfall is in excess of 50 inches per year. Also, it is interesting to note that more than 90 percent of the desalted water in Florida, is used for municipal water supply purposes.

In the past, most desalt plants were built for municipal, industrial or power plant usage and were generally 5 MGD or less. Recently, however, a number of large desalt plants are being constructed in the U. S. and overseas, either for regional water supply purposes (50 MGD R.O. plant in Saudi Arabia) or for water quality improvement (108 MGD Yuma Plant in Arizona).

DESALTING TECHNOLOGY EXPERIENCE FOR WATER QUALITY IMPROVEMENT

A demonstration project report on surface water quality improvement (Rhine River) by use of the desalt technique was published by Kuiper (ref. 9). It was reported that the reverse osmosis technique was most promising in comparison to two other techniques (distillation and electrodialysis) because of its ability to remove both salts and organic pollutants (Table 2).

TABLE 2

The Removal of Pollutants from Surface Water by Means of Different Treatments

	Chlorination	Coagulation	Reverse Osmosis	Active Carbon
Bacteria and viruses	XXX	XXX	XXX	-
Suspended matter	-	XXX	XXX	XX
Total organic carbon	-	XX	XXX	XXX
Pesticides	-	XX	XXX	XX
Inorganic salts	-	-	XXX	-
Inorganic toxic compounds	-	XX-XXX	XXX	-
Ammonia	(XXX)	-	X	-
Phenols	-	-	X	XXX
Taste and odor	-	X	XX-XXX	XXX
Oil	-	X	XXX	XX
Detergents	-	X	XXX	XXX
Hydrocarbons	-	-	X-XX	XXX
Chlorinated hydrocarbons	-	-	X-XX	XXX
Volatile organic acids	-	-	X	XX

TABLE 2 (Con't.)

	Chlorination	Coagulation	Reverse Osmosis	Active Carbon
Carbohydrates Amino acids Fatty acids Proteins	-	X	XXX	XX

XXX 90-100% removal
XX 50-90% removal
X 10-50% removal
\- <10% removal

Table 3 shows the percentage removal of contaminants through combinations of several water treatment techniques. These treatment processes can be utilized either for surface water quality improvement or for renovation of wastewater (ref. 1).

TABLE 3

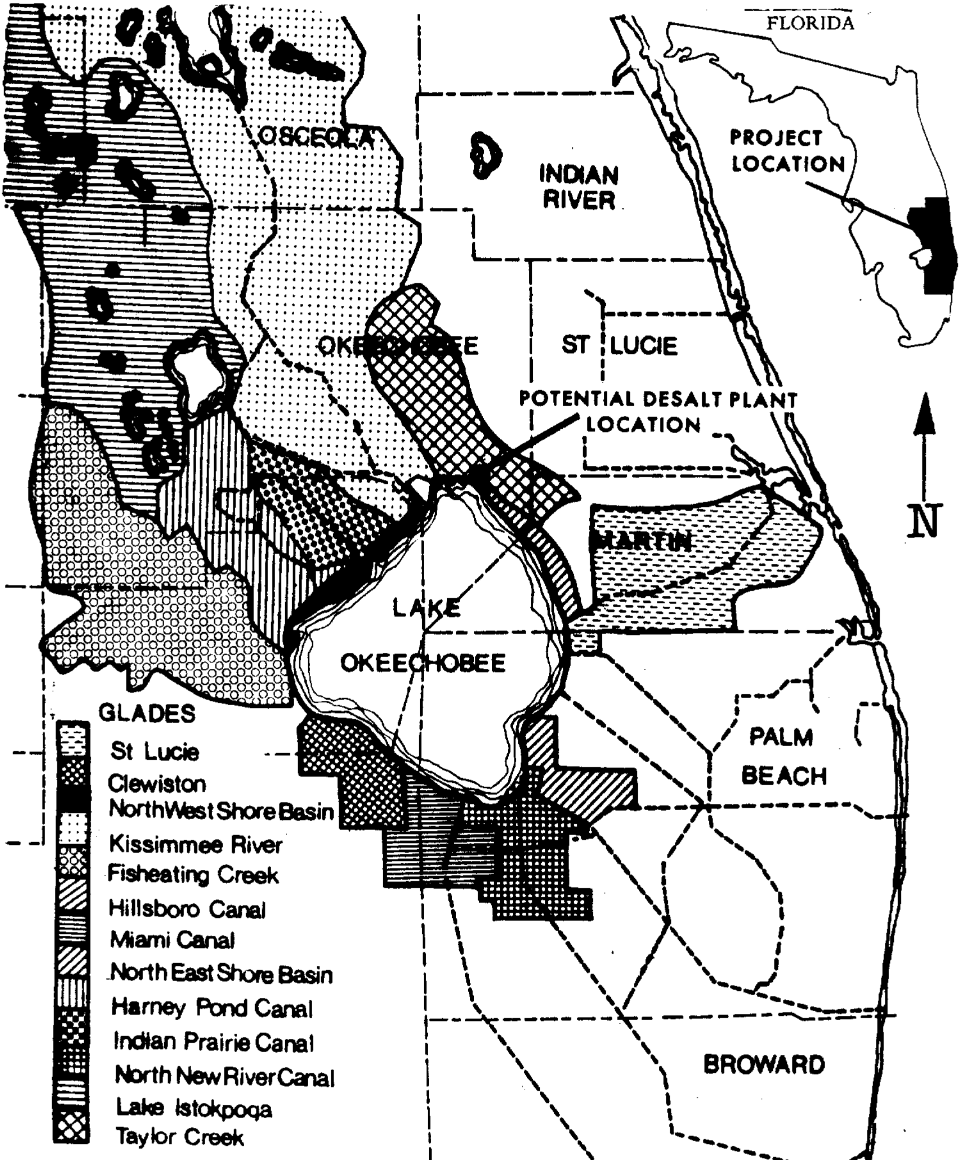
Contaminants Removal by Various Treatment Methods

Combination of treatment processes	Estimated total contaminant removal (%) COD or BOD	Phosphorus	Nitrogen	TDS
(1) Primary + activated sludge (including sludge disposal)	85	-	-	-
(2) Primary + activated sludge + activated carbon	97	-	-	-
(3) Primary + activated sludge + activated carbon + lime treatment + separate nitrification + chlorination	97	98	85	-
(4) Primary + activated sludge + activated carbon + ion exchange + chlorination	98*	99	76(NH_3-N) 86(NO_3-N)	86
(5) Primary + activated sludge + dual media filtration + reverse osmosis	99+*	99.7+	95(NH_3-N) 75(NO_3-N)	95

POTENTIAL FUTURE ROLES FOR LARGE SCALE DESALT PLANTS IN SOUTH FLORIDA

Lake Okeechobee, the second largest freshwater lake totally within the United States, is referred to as the "Liquid Heart" of south Florida. In addition to supplying wellfield recharge to lower east coast counties and irrigation water to the Everglades Agricultural Area (often referred to as the winter vegetable capital of the United States) the Lake also receives return flow containing nutrients (mainly Nitrogen and Phosphorus) from the agricultural land, as well as storm water runoff resulting from heavy rain periods.

Figure 1 depicts the natural as well as manmade drainage basins to the Lake. The natural basin consists of the Kissimmee River, Fisheating Creek, and Taylor Creek and Nubbin Slough. The manmade drainage to the Lake consists of the St. Lucie, Hillsboro, North New River and Miami Canals. These canals can convey water in and out of the Lake depending on specific flood control or water supply situations (ref.4)



DRAINAGE BASINS TO LAKE OKEECHOBEE

FIGURE 1.

Based on several studies it has been concluded that the Lake may be in an early eutrophic condition. The three areas that contribute the highest nutrient loads to the Lake are Taylor Creek - Nubbin Slough, the northern portion of the Everglades Agricultural Area, and the downstream reaches of the lower basin of the Kissimmee River (ref. 3).

Two basic "non-treatment" water management schemes have been recommended to date. They are: 1) a combination of modified surface water management, retention systems and various land use practices designed to keep nutrients in upland areas of the drainage basins and therefore reduce nutrient loadings to surface waters, and 2) reduction of backpumping from the Everglades Ag. Area (ref.3). Strategies employing current and advanced technological capabilities need to be analyzed to provide a range of possible alternatives for decision makers.

DESIGN OF A MULTI-PURPOSE DESALINATION PLANT FOR NUTRIENT REDUCTION OF TAYLOR CREEK - NUBBIN SLOUGH

A preliminary conceptual design for an RO plant to remove in excess of 90% of both total nitrogen and phosphorus has been developed to allow its comparison with other nutrient reduction alternatives. The key hydrologic and nutrient parameters of the Taylor Creek - Nubbin Slough area are given in the table below (ref. 4).

TABLE 4

	NITROGEN				PHOSPHORUS			
Wet Month Avg. Flow MGD	Current Avg. Load Tons	Alloc. to meet Permissible Loadings Tons	Excess Load Above Permissible Tons	% Excess	Current Avg. Load Tons	Alloc. to meet permissible Loadings Tons	Excess Load Above Permissible Tons	% Excess
125	387	106	281	73	160	22	138	86

The plant design would closely follow that of the Yuma facility wherever possible, so as to make maximum use of the development experience at Yuma.

The basic operating mode of the plant would be to use the surface flows from Taylor Creek - Nubbin Slough as primary source water. Product water, free of excess nutrients could then be allowed to flow into Lake Okeechobee. Part of the product water could also be used, depending on the time of year and specific need for furnishing potable water supplies to the expanding urban population of the City of Okeechobee and other rural communities to the north and east of the Lake. In addition, part of the product water could be supplied to agricultural interests, who are the major land users in this section of Florida.

The multiple use of product water makes the plant's long-term potential very flexible towards future water resource applications. For example, during a dry season, or period when additional water supply might be required, source water could be taken from the Floridan aquifer which underlies the entire area. This highly mineralized water source would be an excellent secondary supply in terms of quantity and quality available.

Economic Considerations

Cost effectiveness is the major parameter when the various nutrient reduction alternatives are evaluated. Rough order of magnitude costs for the conceptual design discussed above were developed and compared to those cost projections for the Yuma plant (ref. 7). A third cost comparison was derived from the generalized set of cost curves prepared by the AWWA (ref. 6).

The Taylor Creek - Nubbin Slough plant would require minimum pretreatment compared to the extensive pretreatment planned for the Yuma plant. All cost baselines are updated to Sept. 1978 through the use of the ENRCCI.

The capital and OMR cost equation for R. O. as developed by the SFWMD is:

$$\text{Capital Cost} = 172{,}500 + 1{,}023{,}500\,Q^{.867}$$

$$\text{OMR Cost} = 11{,}500 + 241{,}500\,Q^{.954}$$

Filtration will be employed as the pretreatment method, with cost-equations for this element used as follows:

$$\text{Capital Cost} = 534{,}520\,Q^{.63}$$

$$\text{OMR Cost} = 27{,}945\,Q^{.68} + 2300$$

For a 110 MGD plant, the capital and the OMR cost for a filtration unit would be $9,726,665 and $642,282.

Therefore, the total cost of the Taylor Creek - Nubbin Slough plant would be:

Item	Capital Cost ($\$10^6$)	OMR Cost ($\$10^6$)
R.O. Plant	60.45	21.41
Filtration	9.72	.64
Total	70.17	22.05
Total for Plant Product	55 cents/1000 gallons	

The three cost methodologies compared are shown in the Table below. These are the costs for the basic R.O. and do not include pretreatment or distribution.

TABLE 5

Taylor Creek - Nubbin Slough 110 MGD Desalt Plant Capital and OMR Cost ($ x 10^6)

	YUMA		AWWA		SFWMD DEVELOPED	
	Construction	OMR	Construction	OMR	Construction	OMR
R. O. Plant	137.8	19.81	64.68	22.03	60.45	21.41
Product water Cost/1000 Gals.	$0.50		$0.55		$0.53	

The institutional considerations for this plant could include the sale of potable or subpotable water through several different arrangements. One potential could be a Water Supply Development Authority (WSDA) which would market the water to both wholesale and retail consumers, both agricultural and urban. At a produced cost of 55 cents per 1000 gallons, this water would be within the price range of conventionally produced potable water. Mixed subpotable water would cost considerably less to produce. This could form the basis for an effective dual water supply system.

CONCLUSION

The final assessment of whether a given technology or non-structural method will represent the best answer to the nutrient reduction concerns affecting Lake Okeechobee will come only after a complete comparison by a cost/benefit, expressed preference or other type of approach is accomplished. (Including the consideration of political realities.)

Not enough is known to date about the costs of the other nutrient reduction alternatives. Some, such as new, large surface water storage areas could approach overall plant cost due to high land values and containment costs. Others might result in taking a significant amount of private land out of production and thus result in high overall disbenefits.

In the final analysis, the multiple use flexibility of the large scale demineralization plant should be accounted for and considered in the development of decision-making data and plans.

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VIEW OF THE SFWMD TOWARDS DESALINATION

I. CURRENT STATUS AND TRENDS

The future development of desalination in south Florida over the next 20 to 30 years will be guided by some significant changes in the way our water resources are obtained and used. There are already 24 desal plants operating within the SFWMD; this is about 35% of all the desal plants in Florida, so there is a basis on which projections and comments can be made.

The major changes that are likely to impact the degree to which desalination is applied in south Florida include:

1. Increased population growth and agricultural production will require substantial new water supplies. (For the five largest or fastest growing counties of Dade, Broward, Palm Beach, Lee and Collier, over 375 MGD of additional supply will have to be made available between 1980 and 2000, if average growth projections actually occur).
2. New federal water quality initiatives towards drinking water supplies will require expensive additional treatment systems. (EPA is evaluating several hundred constituents in drinking water, some of which will eventually be brought under control. Desalination is especially effective as a water treatment process in addition to its ability as a supplemental water source).
3. Social and psychological concerns pertaining to risk factors of future water supplies. (The probability of adequate future rainfall is greatly influenced by assumptions made on atmospheric cooling or heating, the degree to which weather modification will be used, etc.).
4. The role of progress of newly evolving water supply technologies such as wastewater reuse, dual water supply, and deep aquifer storage. (Some of these systems may use desalination as one stage of their total treatment process).

Each of the above, either separately or in combination, will tend to increase the demand for desalination plants, if these factors continue according to present trends.

II. SOME BACKGROUND ON A MAJOR PROBLEM AREA

While desalination as a water supply and treatment process is not new to south Florida, there have been misunderstandings about its capabilities and costs due to the many types of systems available and types of treatment attempted.

There are three "types" of water available in south Florida that are future candidates for desalination;

1. Seawater (very salty water obtained from ocean or gulf)
2. Brackish water (slightly salty water from a deep aquifer such as the Floridan or surface water body)
3. Potable water (generally obtained from a shallow aquifer).

Desal plants are generally planned to treat only one of the above types, and changing a "raw" water source after operations start requires extensive modifications depending on the specific process selected. This is precisely what happened in the case of the Key West desal plant you have been hearing about so much lately. This plant was designed to treat sea-water, but brackish aquifer water was used instead. The excessive mineral-ization of the aquifer's brackish water clogged the tubes in the plant and ever since the early 1970's this has created tube fouling and other problems.

Had this plant been used for what it was originally designed for, its operation would have been much more reliable. Distillation desal units, similar to the Key West plant, now account for 86 of the 162 plants over 1 MGD in capacity throughout the world, (or about 53%).

Needless to say, this situation in Key West has identified all desalination (regardless of type of process) with the Key West problem.

III. POTENTIAL FUTURE APPLICATION

The future potential for desalination in south Florida can be categorized into three major areas;

1. Applications which supplement or extend conventional water supply and treatment facilities (especially those that have present or imminent saltwater intrusion problems in their shallow aquifer sources).
2. Applications which provide new capabilities required by drinking water quality regulations or new technological systems such as deep aquifer storage or recharge.
3. Advanced applications which make use of current R & D to develop large-scale, cost-effective plants. (Such as 100 MGD plants which could serve a variety of water resource needs including drinking water production, agricultural supply, natural system enhancement, etc.).

These potentials can only be fulfilled if some of the old and new problem areas about desalination can be overcome or at least put in the proper perspective. One of these was previously discussed in relation to the Key West Distillation plant. Others include:

1. Energy costs for desalination are much higher than for conventional treatment processes. (This is true, but other desalination process costs are lower, so that in the end result, the cost per 1000 gallons of produced water of desalination is competitive in most cases with that of a conventional plant. In addition, the desal process has a much greater flexibility towards dealing with new water quality regulations that might be instituted in the future, and this is usually not included in cost-effectiveness calculations).

2. Utility personnel and engineering consultants would rather deal with conventional treatment systems than desalination systems. (Some of this "bias" is undoubtedly due to the Key West syndrome, but much is due to a lack of experience and information in dealing with the newer desal processes).

IV. PREVIOUS SFWMD DESAL ACTIVITIES

The SFWMD has, and will continue to support, the logical development of desalination in south Florida. Over the past four years we have:

1. Initiated and sponsored symposiums which bring together system manufacturers and government/utility personnel and consultants from local areas to discuss desal process background, capabilities and characteristics.
2. Included in south Florida's regional Water Use Plan data and analyses relating desalination to other water supply alternatives for the most effective use of future water resources.
3. Provided data and interchanged results on the desal plants operating in south Florida through technical papers, and other participation in national and international forums.
4. Sponsored operator courses in desalination through a local academic institution.
5. Provided technical training personnel for the Fairley-Dickinson desalination course.

V. SUGGESTED FUTURE APPROACHES

In order to assure the desalination process receives an adequate and accurate assessment in terms of future water resource alternatives, the following approaches will most likely be used and/or attempted by the SFWMD:

1. Continued translation of desal system facts and capabilities to the local government level by bringing together manufacturers and local engineering personnel.
2. Recommendations in the District Water Use Plan that any new or expanded water treatment/supply facility consider desalination as a required alternative that should be evaluated when design studies are being started.
3. Maintaining an up-to-date awareness of the progress being made in desal technologies so that any new capabilities can be applied in south Florida where appropriate.
4. The conduct of advanced system level analyses to allow evaluation of south Florida's specific climatic and water resource characteristics with respect to desal process development (e.g., the use of large-scale plants in combination with solar power sources or ocean current energy conversion, etc.).
5. Support of academic courses dedicated to improving general and engineering levels of understanding of desalination.